

Aeroelastic code validation - A mixed collection of examples

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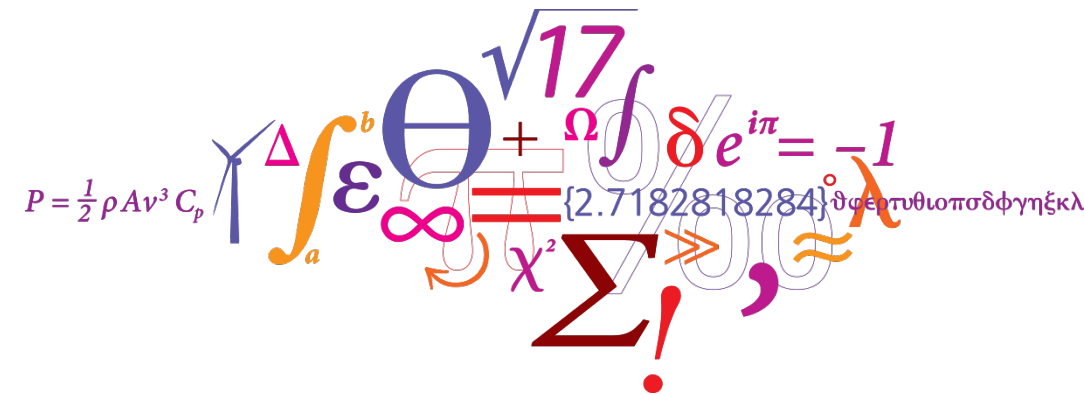
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Aeroelastic code validation

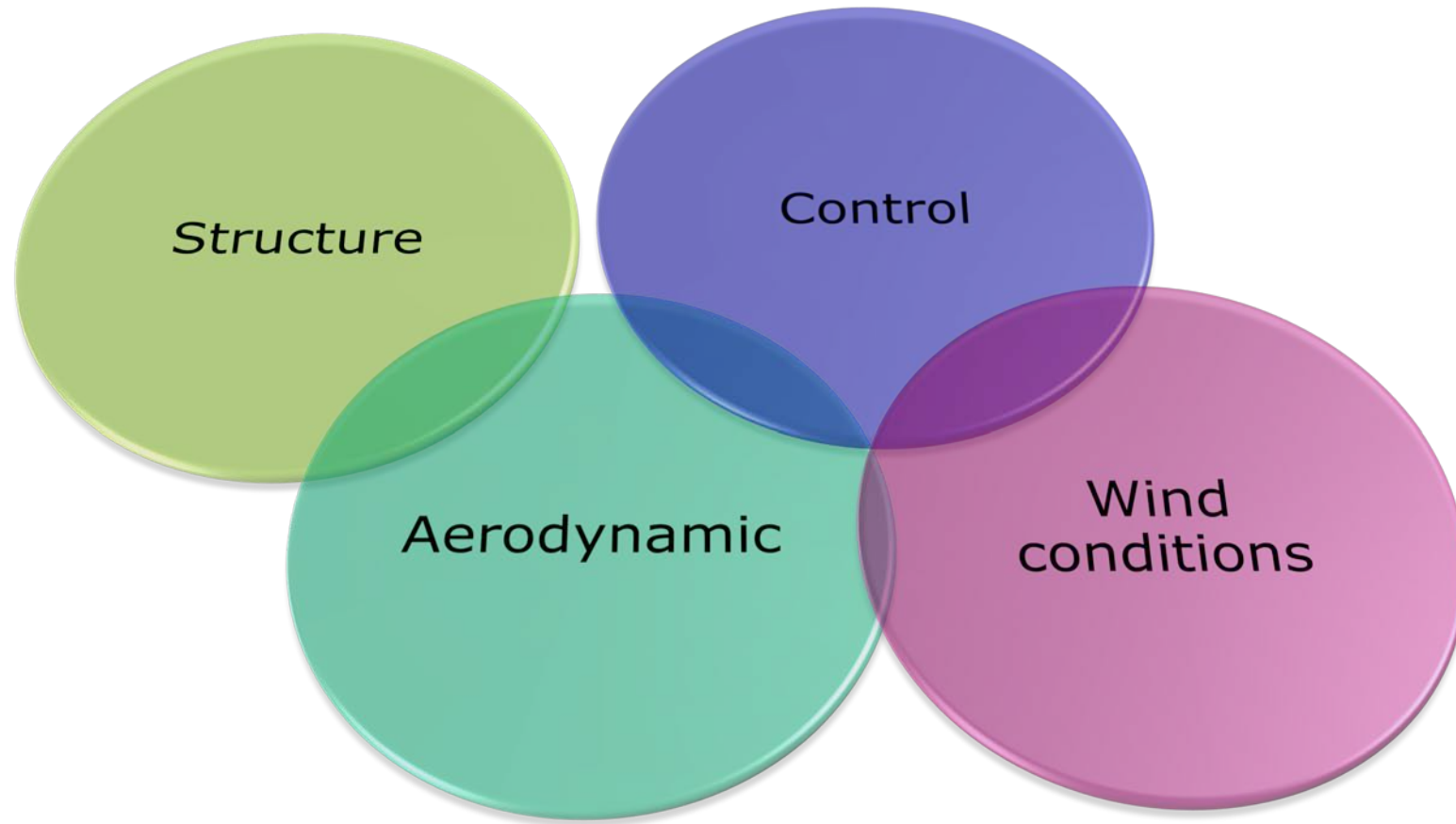
- A mixed collection of examples

Torben J. Larsen

IEA Wind Task 11
Scotland 06.09.2017

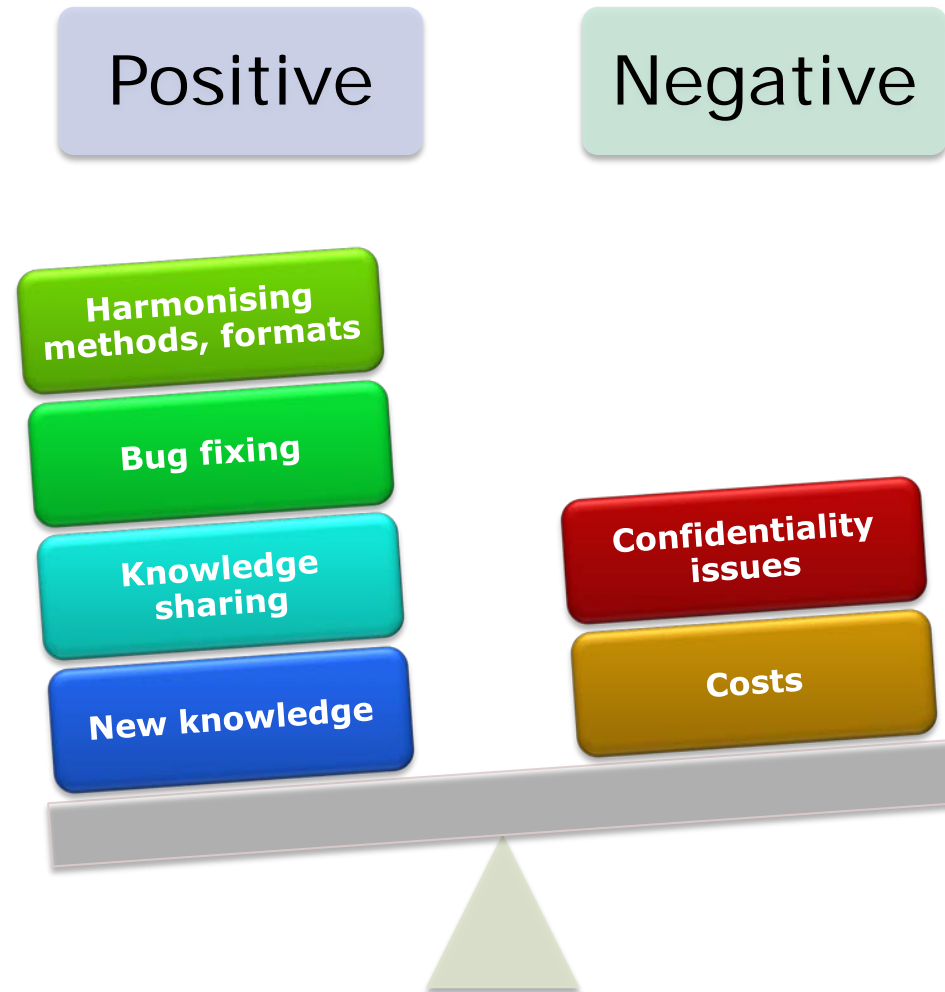


The four load drivers



We can choose to focus on individual areas, but all has to be OK for the loads to be correct

What do we want to achieve?



- Code-2-code comparison
 - Codes of same complexity level
 - Codes of varying complexity
- Code-2-controlled experiments
 - Eg wind tunnel experiments
 - Floating wind turbine tests
- Code-2-fullscale experiments
 - Wind turbine level
 - Wind farm level

OC3, OC4, (OC5) Code-2-code

- Public fictive reference turbine generated
- Comparing in steps. Start simple – advance gradually
- Comparison possible also for new types of concepts
- Great for knowledge sharing, interesting discussions
- Enabled a much bigger community within (relevant) wind turbine load simulations

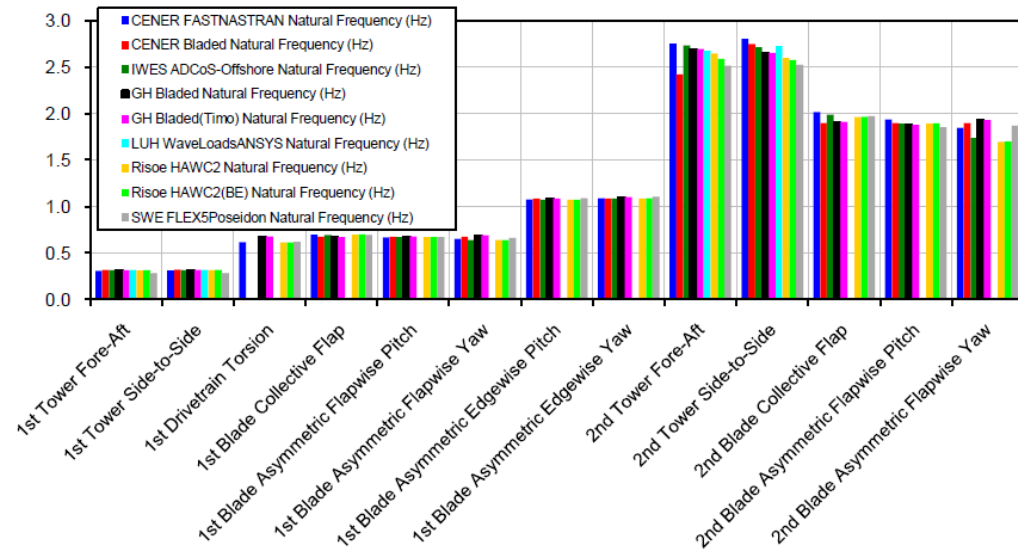
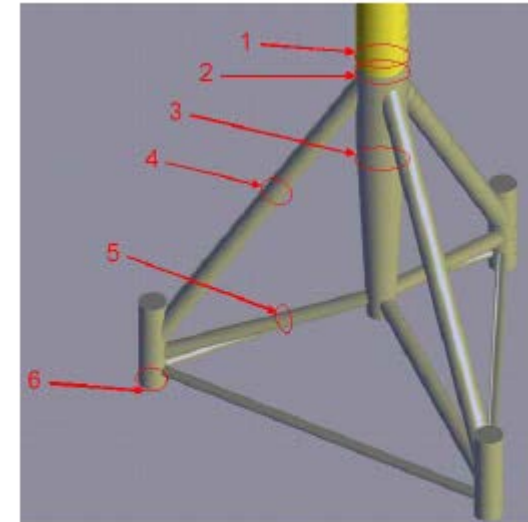


Figure 20. Full-system natural frequencies from load case 1.2

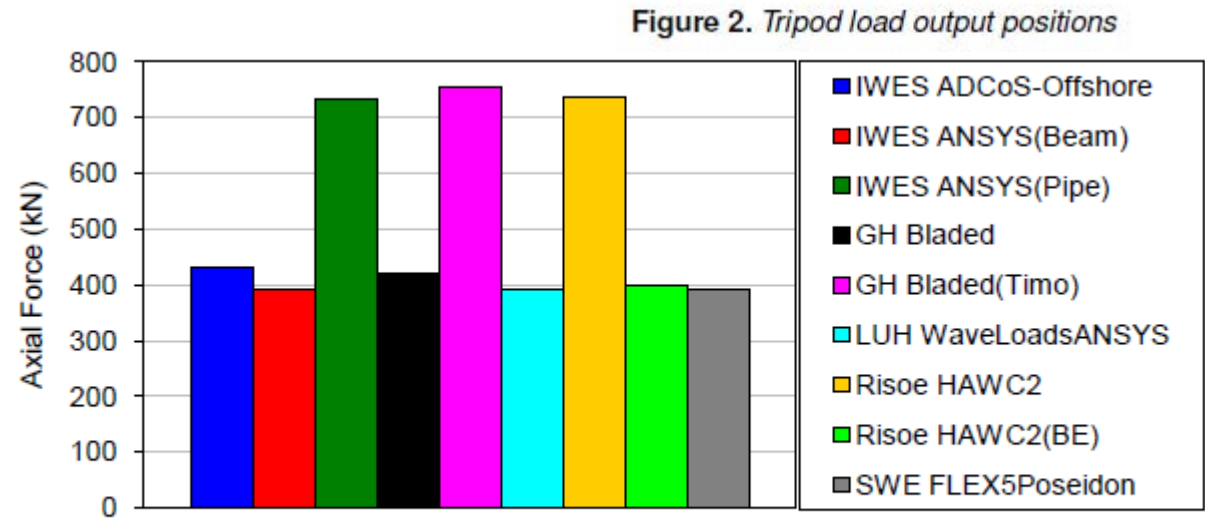
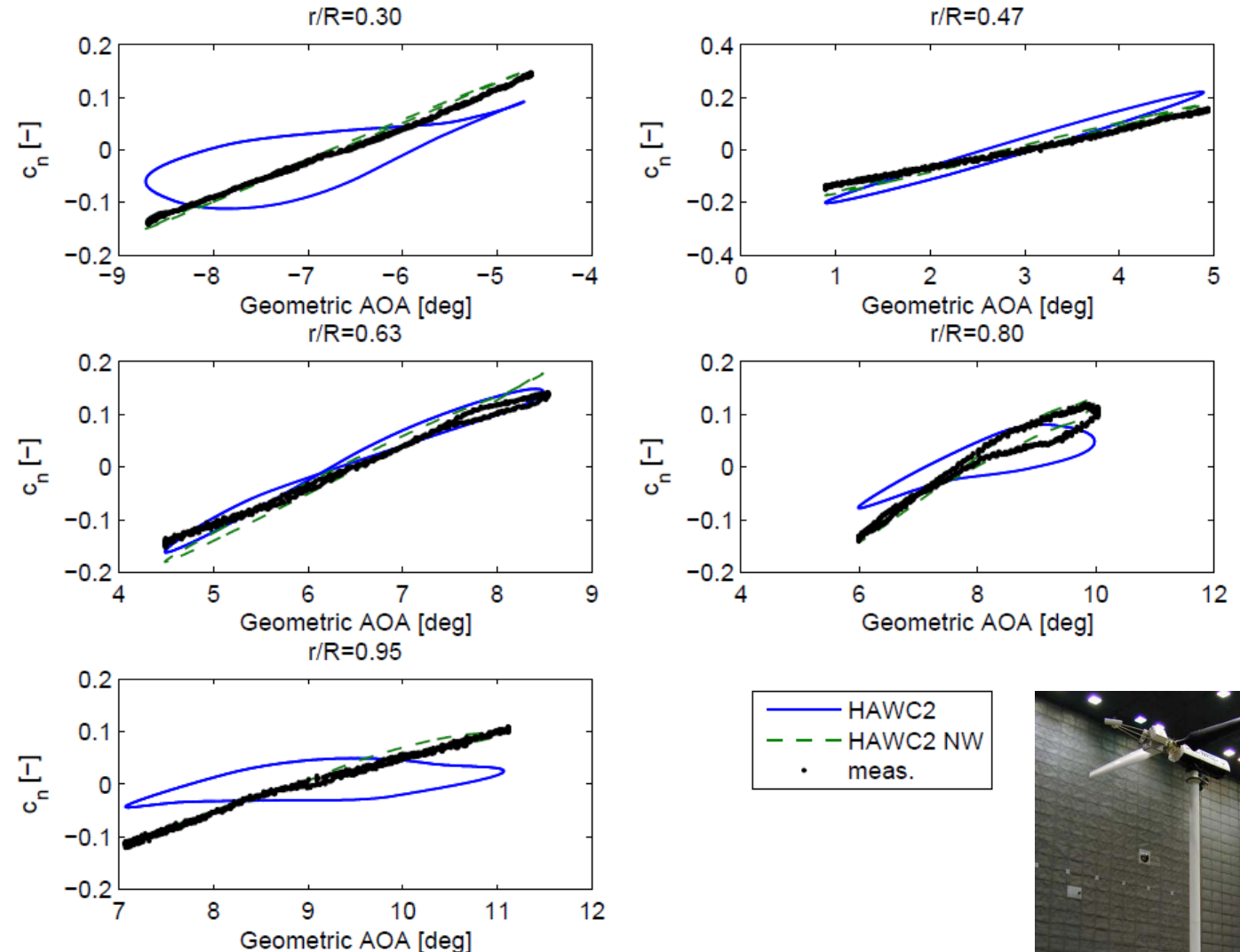


Figure 18. Axial force 10 m under MSL in the central column of the tripod (location 3 as described in Figure 2)

Dedicated experiments

- NREL/NASA phase VI experiment
- Example of Stand still situation with pitching blades
- Pitch amplitude 2deg
- Wind speed 23.3m/s
- Comparison with HAWC2 results and HAWC2 with a nearwake model



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Trailed vorticity modeling for aeroelastic wind turbine simulations in stand still

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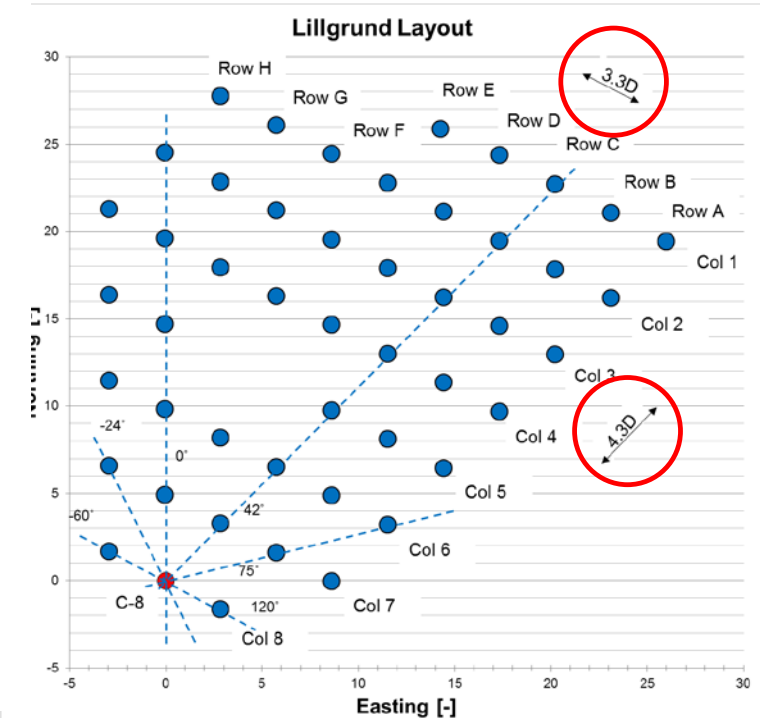
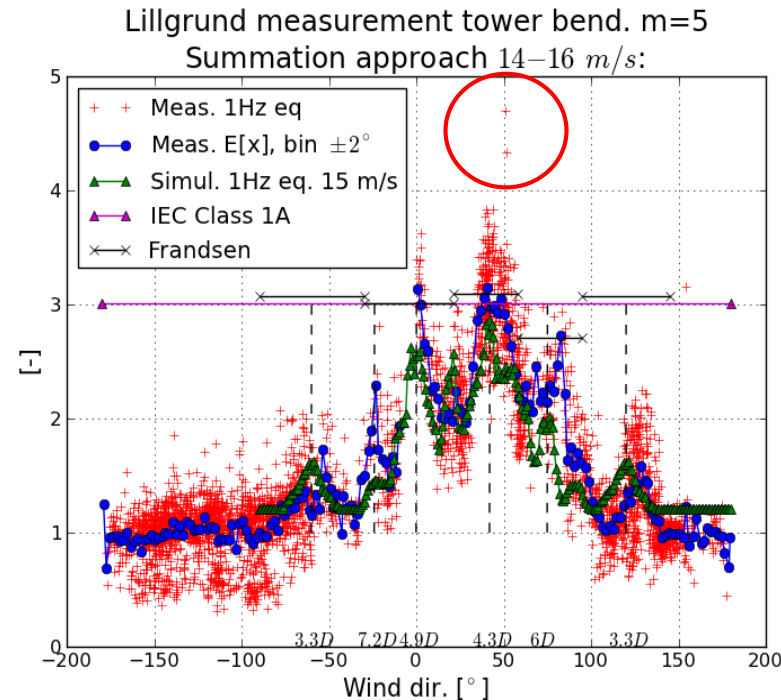
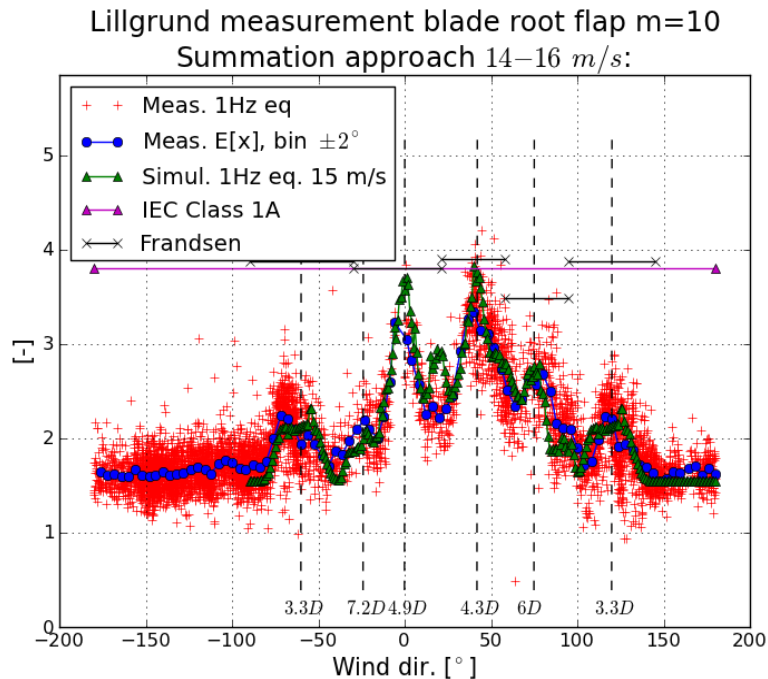


Previous results Lillgrund - 2015

17 - 20 November 2015 | Porte de Versailles Pavillon 1, Paris, France

Wake effects above rated wind speed. An overlooked contributor to high loads in wind farms.

T.J. Larsen, G. Larsen, H.A. Madsen and S.M. Petersen

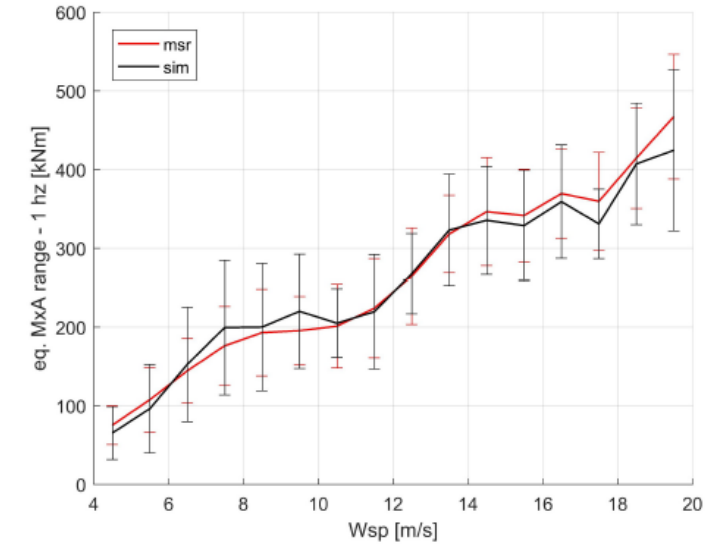
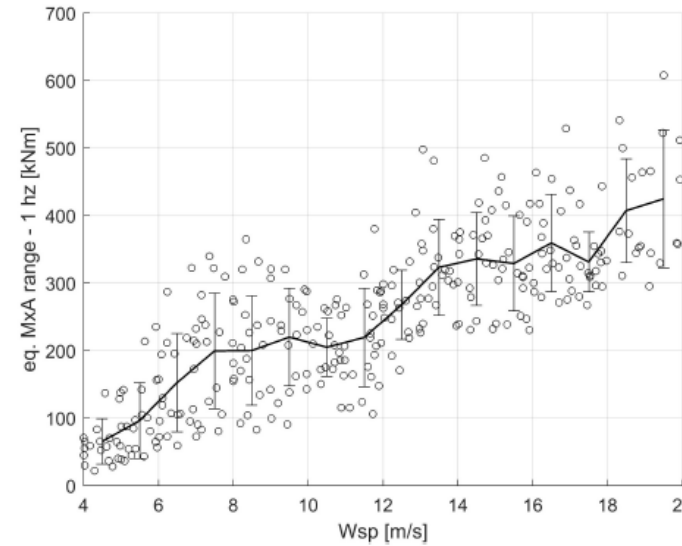


14-16m/s

- Generally a very good to excellent agreement is seen
- High wind speed situations are highly important
- What happens in the “outlier” situations?

The V52 DTU test facility

- Fully instrumented V52 turbine (pitch, speed, power, strain gauges, accelerometers)
- Met mast in western sector
- LIDAR in nacelle in upwind configuration
- Inflow with 5-hole pitot tube
- Spinner anemometer
- Aeroelastic model
- Ongoing project for creating one-2-one sim/meas comparisons



West

North

East

South



Increasing the wind field information

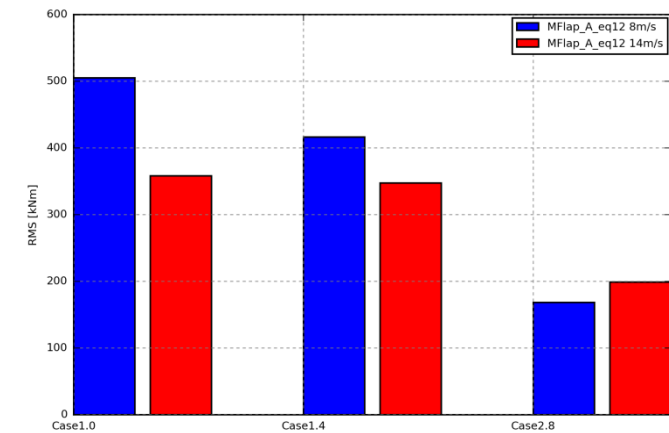
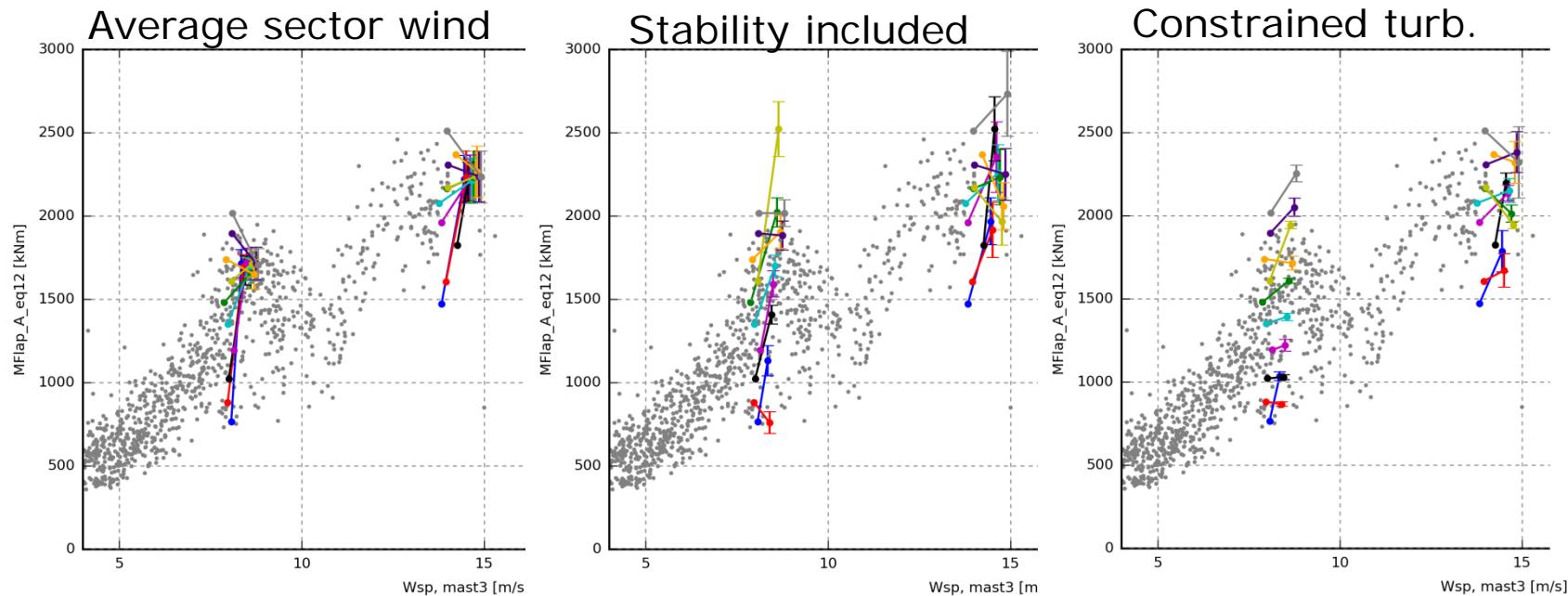
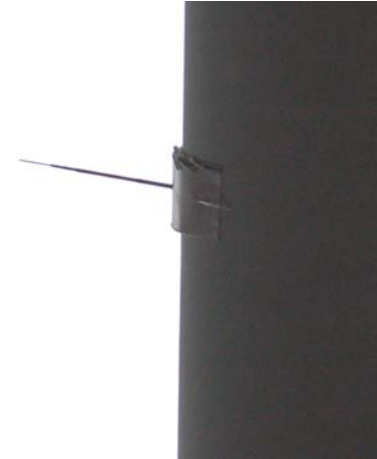
Siemens SWT 3.6MW Tjæreborg

Pitot tube installed on one blade

Free wind information derived based on pitot measurements and an inverse induction model

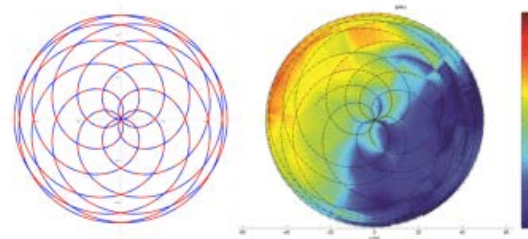
Courtesy: Siemens Wind Power

Mads M. Pedersen, DTU Wind Energy

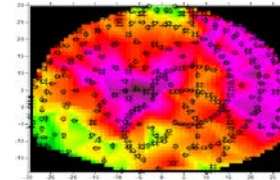


Spinner LIDARS provide unique options

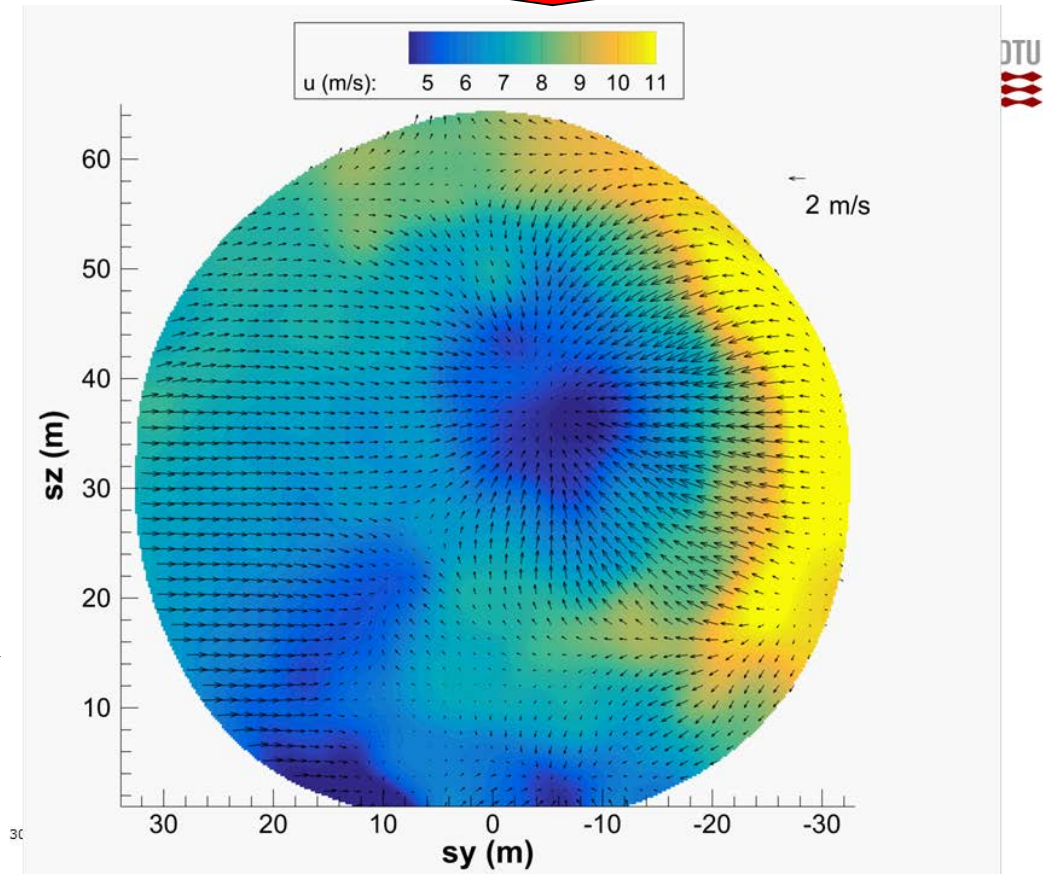
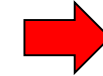
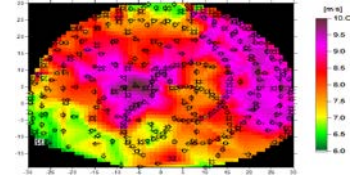
- Lidars techniques evolves very quickly
- DTU Spinner LIDAR scans a full disc in 2 sec (LOS)
- Using a linearized flow solver a good estimate of u, v, w components can be found
- This could remove most of the uncertainty related to the windfield



LIDAR V_{LOS}



LINCOM V_{LOS}



Courtesy: Mikkel Sjøholm,
Torben Mikkelsen
DTU Wind Energy

$$\begin{aligned}
 U \frac{\partial u}{\partial x} + V \frac{\partial u}{\partial y} + W \frac{\partial u}{\partial z} &= -\frac{\partial}{\partial x} \frac{p}{\rho} + K_{xy} \left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right] + K_z \frac{\partial^2 u}{\partial z^2} \\
 U \frac{\partial v}{\partial x} + V \frac{\partial v}{\partial y} + W \frac{\partial v}{\partial z} &= -\frac{\partial}{\partial y} \frac{p}{\rho} + K_{xy} \left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right] + K_z \frac{\partial^2 v}{\partial z^2} \\
 U \frac{\partial w}{\partial x} + V \frac{\partial w}{\partial y} + W \frac{\partial w}{\partial z} &= -\frac{\partial}{\partial z} \frac{p}{\rho} + K_{xy} \left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right] + K_z \frac{\partial^2 w}{\partial z^2} \\
 \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} &= 0
 \end{aligned}$$

Summary

- Code 2 code validation
 - Very good for knowledge sharing
 - Great for bug fixing
 - Testing of details that may be difficult to test in experiments
 - Cost are low
 - Reference is missing
- Code 2 controlled experiments
 - Often new knowledge
 - Mexico, New Mexico
 - Test of floating wind turbines
- Code 2 controlled experiments
 - New knowledge and understanding
 - Focus on details
 - The big picture is missing
 - Issues with scaling, Re numbers, boundary effects etc.
- Full scale experiments
 - Excellent for new knowledge
 - All aspects included
 - Costly, confusing, confidentiality issues
 - New flow measurement options may bring it closer to a controlled experiment!